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Agricultural Memorandum No. 918

THE PLASTIC COVERED SHEEP HOUSE
AN INVESTIGATION TO ASSESS THE INTERNAL CLIMATE

by L.G. Bird

1. INTRODUCTION

Interest has recently been increasing in the use of plastic covered sheep houses. These are usually larger and sturdier versions of what have hitherto been known in the horticulture industry as 'plastic tunnels' but modified by the inclusion of openings both at the sides and ridge so as to provide ventilation for the housed animals. The sheep are put into the house in late December or early January and remain in the house until just after lambing in late March.

Setting aside the general economics of the cost of providing housing for sheep at all, the proponents of such houses usually include the following amongst the advantages of housing sheep:-

(a) The animals are kept dry and protected against the rigours of the weather.

(b) Feeding and treatments against animal disorders may be readily monitored and controlled.

(c) The quality of the fleece may be improved by being less greasy and containing less vegetable matter.

(d) The ground ordinarily used for grazing is 'rested' and grass swards are improved, particularly where poaching is a problem.

(e) Lambing percentages are raised.

Exploratory measurements made in such a house in February 1980 when 220 ewes were housed, showed that in the calm weather conditions prevailing, temperature gradients developed along the house soon after the end doors were closed.

This particular house (Fig. 1) which is at Gorfenletch Farm, near Morpeth, Northumberland is 60 m long, 9 m wide and is fitted with side and roof vents. (Figs. 2 and 3). Pressed metal sheeting (Fig. 4) deflects air entering the side vents up towards the roof so reducing the risk of draughts at ground level. The long axis of the house is orientated N-S and on such a slope that the N end is 2 m higher than the S end.

With the north door closed inert smoke released at the open southern entrance door moved through the house and became stagnant in the roof space above the door at the upslope end of the house where also the humidity was seen to increase. It thus appeared that the 2 m difference in height along the length of the house was helping to promote ventilation by the 'stack effect' in which air moves from the lower to the higher of two openings in a building if intervening heat is supplied artifically, by the sun or by animals within the building.

Since February 1980 much of the continuous plastic sheeting of the end walls of the house (Fig. 5) has been replaced by two layers of plastic mesh and the end doors extended to almost the full height of the end wall (Fig. 6) to improve ventilation and access.

A second house is now in place, 5 m to the east of and parallel to the first, but roofed with a tough white plastic sheeting instead of the translucent sheeting used to cover the first house. (Fig. 1)

In order that advice on the siting and management of such houses may be prepared three periods of measurement were made in the recently built house during the winter of 1980-81 at Gorfenletch Farm.

The objectives were to measure by how much:-

(a) the climate inside the house covered by the white opaque material differed from that outside,

(b) the climate varied within the house,

Measurements were made:-

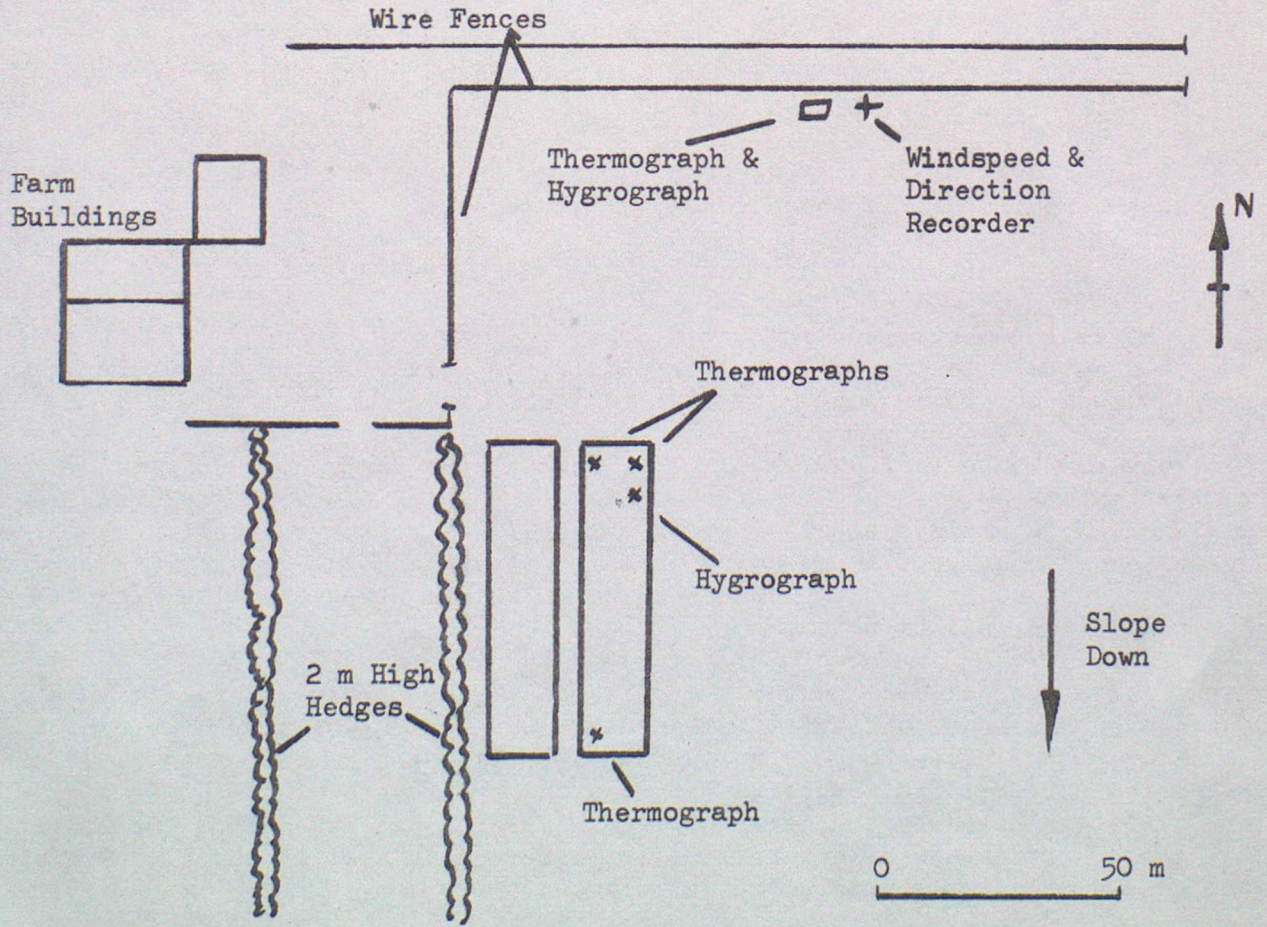
(c) before the animals were housed, (11-17 December 1980),

(d) during a 'cold' part of the housing period, (7-28 January 1981),

(e) during a 'warm' part of the housing period, (3-16 March 1981).

Recording equipment was removed from the house on the 17 March so as not to interfere with lambing.

2. THE SITE



Gorfenletch Farm buildings are at a height of 120 m ASL on the top of a slight ridge in gently undulating country some 15 Km inland from Dunridge Bay on the Northumberland coast.

Trees within a 700 m radius of the farm are few and generally only 5-8 m tall or are in hollows which reduces their effective height as an obstruction to the wind. Thus the sheep houses are exposed to winds from most directions, being protected only from winds between NW and W by the farm buildings themselves and by a 1-2 m high hedge which runs N-S some 3-4 m to the W of the houses. (Fig. 1)

3. EQUIPMENT

The external climate was measured by a wind speed and direction recorder, mounted at a height of 2 m, together with a hair hygrograph and bimetallic thermograph housed in a Stevenson screen installed to the east of the farm buildings and 70 m to the NE of the sheep houses. (Fig. 7)

Inside the newly erected house continuous records of temperature were made at the lower end and at each side at the upper end of the house by bimetallic thermographs suspended, from the roof members in home-made 'screens', so as to be at a height of 1.9 m. (Fig. 8). Careful measurements showed that the radiation error of these screens in bright sunshine was about +0.8°C, similar to that of the Stevenson screen. A hair hygrograph was also suspended at the upper end alongside, and at the same height as, one of the thermographs.

NOTE: It had previously been noted that thermographs occasionally suffered small changes of zero during long journeys by road no matter how carefully they are packed or protected from vibration. Accordingly the zero screws of all thermographs used at Gorfenletch were fitted with lock nuts.

4. RESULTS

The results are presented in full to allow further study. The weather of each weekly period is described and tables of hourly run of wind, maximum and minimum temperatures together with facsimiles of thermograph charts are appended. The humidity at 1400 hrs is shown on the thermograph charts.

5. 1ST PERIOD - 11-17 DECEMBER 1980, HOUSE EMPTY (Tables 1 and 2, Charts 1-4)

The average wind throughout this period was 18.6 Kph and there were no periods of calm. Speeds of below 10 Kph were rarely recorded and then only for an hour or two. The strongest wind of 49 Kph occurred on the 14th when during a period of 9 hours the wind speed averaged 41 Kph. In the mainly cloudy conditions the average temperature outside and inside the house were almost identical (see Table 2). Thus, though the end doors were closed for much of the time, adequate ventilation was afforded by the fixed openings in the sides and top of the plastic cladding and by the mesh covered ends of the house. Records from the thermographs within the house showed that for 90% of the period temperature differences within the house were less than 1°C. On three days, however, between the hours of 1100 and 1400 G when cloud amounts were low, the southern end of the house became warmer than both the northern end of the house and the air outside by 2-3°C. Radiation from the sun which at this time of year reaches a maximum altitude of only 13° will strike the roof covering of the house at a grazing angle and be largely reflected away. By contrast, however, the dark coloured plastic mesh of the southern end of the house which is almost normal to the sun around mid-day will absorb heat and air in the southern end of the house will be warmed by contact.

Hygrograph records showed that the humidity inside the house was mostly 2-3% lower than that outside except for during the three short periods of mid-day warming when the humidity inside the house was as much as 15% lower than that outside.

6. 2ND PERIOD - 7-13 JANUARY 1981 - 220 EWES HOUSED
(Tables 3 and 4, Charts 5-8)

Conditions were again generally windy with outside air temperatures at or below 0°C for about 30% of the time. There were no periods of calm. Speeds of less than 10 Kph were recorded for only 15 hours (on the 7th) and thereafter daily averages were between 16 and 26 Kph. The strongest wind of 42 Kph was measured during the evening of the 12th during a 16 hour period during which the average wind speed was 30 Kph. The mean speed over the whole period was 19.5 Kph.

The end doors were kept shut for most of the time and invariably at night.

From Tables 3 and 4 it will be seen that in this generally windy period the mean maximum temperature within the house was only 1.0°C higher than that outside whereas the mean minimum temperature was 1.9°C higher than that outside.

Small temperature gradients did occur within the house, however, the thermograph records showing the the NE corner was for most of the time 0.5-1.0°C warmer than the NW corner and southern end of the house when the outside wind was stronger than 10-14 Kph. During a sunless period with lighter winds, however, on the 7th and 8th the north east corner of the house was about 2°C warmer than the southern end.

The humidity in and out of the house was very similar until the 8-9th after which the daytime humidities within the house tended to be lower than those outside by as much as 20% for spells of several hours, particularly when the southern end warming occurred.

In strong wind conditions the house appeared to be well ventilated even with the end doors closed. The largest differences of temperature between the house and outside occurred when, during daylight hours, light winds coincided with clear skies. The most notable of these occasions so far was around mid-day on the 9 January 1981. Between 1100 G and 1400 G while the outside temperature rose by only 2°C the temperature just inside the southern end of the house rose by 6.5°C. Even though it had not been possible to keep a detailed record of door opening and closing times it was clear that the end doors must have been closed. Such a large difference of temperature is unlikely to have developed in the 13 Kph wind blowing at the time had the doors been open.

So as to be able to relate door operation more closely to internal temperature changes a Woelfle wind speed and direction recorder was then installed at the mid-point of the house and with its cups and vane at a height of 2 m. (See Fig. 9). Recordings were continued to the 29 January 1981.

7. 2ND PERIOD - 15-21 JANUARY 1981 - 220 EWES HOUSED
(Tables 5 and 6, Charts 9-12)

The weather continued cold but with a number of clear periods. Winds were less strong than the previous week, below 10 Kph for 40% of the time, but there were no periods of calm. The strongest wind of 30 Kph was recorded for one hour only during the evening of the 21st. The mean speed over the whole period was 12.3 Kph, making a total run of wind outside of 2066 Km.

The end doors were kept shut for most of the time and invariably at night. The wind speed and direction recorder mounted at the mid-point of the house (Fig. 9) showed however than 40 Km run of air passed through the house. The recorder, though sensitive, requires air to pass its cups at 1.8 Km/hr (0.5 m/sec) before it will record. The 40 Km recorded is thus an underestimate of the true air flow but calculations based on this figure show that each ewe would have received, an average of at least 0.3 cu. m/minute of fresh air throughout the week.

Outside air temperature remained below 3°C from the 15th until early on the 21st, the lowest temperature of -6.0°C being recorded on the morning of the 16th, during a 48 hour period in which the temperature remained below 0°C throughout. At the end of the week maximum temperatures of 8°C were recorded in milder weather.

Table 6 shows that the mean maximum temperature within the house was 1.7°C higher than that outside and the mean minimum temperature was 0.7°C higher than that outside. On most mornings the NE corner of the house was 1°C warmer than the NW corner and 2°C warmer than the southern end. After mid-day on clear afternoons, however, the NW corner became 1-2°C warmer than the NE corner but during these clear periods the southern end of the house was typically 3-4°C warmer than the northern end of the house and up to 4.9°C warmer than outside. At this time the sun was reaching a maximum elevation of 17° and setting, by 1600 GMT, at a bearing of 240°.

The rate of temperature rise in these clear periods is noteworthy; the temperature at the southern end of the house rising usually 4-6° in 4-5 hours. On the 15 January, however, the temperature there rose 8.5°C in 4½ hours during which time the temperature outside rose by only 2.5°C.

The relative humidity inside the house was generally within a few per cent of that outside which was generally 80-90%. During the clear mid-day periods, however, the humidity within the house was usually 7-10% below that outside.

8. 2ND PERIOD - 22-28 JANUARY 1981 - 220 EWES HOUSED
(Tables 7 and 8, Charts 13-16)

The weather was mild for this time of year with clear periods around mid-day on most days. The wind averaged 13.0 Kph throughout the week but was below 10 Kph for only 14 hours. The strongest hourly wind of 23 Kph occurred on the 23rd.

The run of wind outside totalled 2177 Km while that inside the house totalled 24 Km. Thus each animal received, on average, a minimum of 0.18 cu.m of fresh air each minute.

Maximum temperatures within the house were on average 2.4°C higher than those outside with minima on average within 0.4°C of each other. The by now familiar pattern in which the east side of the house is warmed more than the west in the morning and vice versa in the afternoon was repeated. During warming of the southern end of the house in clear mid-day periods gradients of 4°C developed within the house.

9. 3RD PERIOD - 3-9 MARCH 1981 - 220 EWES HOUSED
(Tables 9 and 10, Charts 17-20)

The cold and cloudy weather with light winds on the 3rd, 4th and 5th (see Table 9) gave way to a mobile south westerly with strong winds. These averaged 16 Kph for the rest of the week, but were 20-30 Kph for much of the 7th-8th during which period the highest hourly run of wind was 34 Kph. The average wind for the whole week was 12.9 Kph.

The end doors of the house were being left open during warmer spells and Table 9 shows that for 50% of the total time a wind of 1-4 Kph blew up the slope through the house. When the wind outside was from the south, even with the house doors open, the flow at the mid-point of the house was reduced to about 1/10 of the speed outside. The door area at the southern end of the house was about 1/7 the area of the end wall.

The freezing outside air temperatures at the beginning of the week rose to 10-11°C by the 7th.

The sun was by now reaching an elevation of 30° and setting at 260° at 1700 GMT. Thus on clear afternoons the whole of the west side of the house was being more evenly warmed than in December and the highest temperatures were measured as frequently in the NW corner as in the southern end of the house.

The mean maximum temperature within the house was now 4.5°C higher than that outside but during the afternoon of the 7th the west side of the house at 16.5° (NW) was 5.2°C warmer than outside.

The mean minimum temperature was 1.8°C higher than that outside with the largest difference being on the 5th when the mean house minimum temperature was 2.3°C higher than the outside minimum.

The humidity remained above 80% except for during the warmer spell of the 9th when it fell briefly to 52% outside and to 65% in the house.

10. 3RD PERIOD - 10-16 MARCH 1981 - 220 EWES HOUSED
(Tables 11 and 12, Charts 21-24)

Wind speed averaged about 10 Kph for much of the week but on the last day averaged 15.6 Kph. When doors were left open air flows of 1-3 Kph were recorded at the mid-point of the house.

During the period a run of wind of 1925 Km was measured outside the house and 27 Km was measured in the house. Thus each animal received on average a minimum of 0.20 cu.m of fresh air each minute during the week.

The mean maximum temperature within the house was, at 11.9°C, some 4.9°C higher than the mean maximum outside. On the 11th when the maximum reached 12.0°C outside, maximum temperatures of 20.1°C and 19.0°C were recorded in the NW and SW corners of the house respectively. At this time while a W'ly wind of 20 Kph was blowing the flow within the house was less than 0.5 Kph.

Mean minimum temperatures within the house were 2.8°C higher than outside.

During the first half of March more than two to three times the usual rainfall fell in the Gorfenletch area keeping the ground around the houses wet throughout. Thus the humidity remained generally above 80% and even in the warm spells there was very little difference between humidity in and out of the house.

11. COMPARISON OF HOUSE CONDITIONS WITH OUTSIDE CLIMATE

(a) Rainfall. The plastic house gave the animals complete protection from rainfall. On a few occasions, however, rainfall in strong E'ly winds was blown up the windward side of the house and entered the roof vents causing wetting of the central access passage.

(b) Wind. The house reduced the air flow over the animals to less than 5% of the wind speed measured in the field at 2 m. Some draughts were experienced in the pens nearest the end doors particularly in N'ly or S'ly flows but these were quickly dissipated in the body of the house.

(c) Humidity. The humidity levels within the house were generally lower than those recorded outside, the moisture contribution by the animals being outweighed by the higher house temperatures.

(d) Temperature. Temperatures recorded in the house were at all times higher than those recorded outside, being 1-2°C higher at night and during cloudy windy spells.

On cloudy nights, with the house doors closed, even in light wind conditions the lift in house temperature over that outside was rarely more than 2°C and on clear nights with light winds, minimum air temperatures in the house were usually as low as (within 1°C) the temperature outside.

On cloudy windy days even with the doors closed the house temperature was rarely more than 2°C higher than the temperature outside, and on cloudy, light wind days the same result was achieved by judicious opening of the doors.

Marked rises of house temperature occurred, however, during the day when clear skies coincided with calm or very light winds. In these conditions the house temperature was occasionally 2° higher than outside in December (when the house was empty), 3-5°C higher than outside in January and generally 5-7°C higher than outside in March. The largest difference recorded was 8°C on 12 March.

12. VARIATION OF CLIMATE WITHIN THE HOUSE

(a) From visual observation, differences of air flow in the house appeared to occur only within 4-5 m of the end doors and mainly when the doors were open and the outside wind direction was within a few degrees of north or south.

(b) Temperature gradients which occurred were closely linked to the altitude and bearing of the sun. Thus in December and early January when the sun was at low altitude, the southern end of the house was often warmer than the northern end by as much as 4°C. From mid-January and during the March measuring period, with the sun higher in the sky, gradients developed in the E-W direction the east side of the house being warmer than the west side in the morning and vice versa in the afternoon.

13. EFFECT OF STRONG WIND ON THE STRUCTURE

The house is of semi-rigid construction but in light to moderate winds movement of the house was negligible. During periods of strong winds between 12 and 14 December, however, flexing of the house caused the thermographs suspended in the house to produce a wide 'ribbon' of trace. The wind record showed that this 'resonance' occurred at speeds above 25 Kph, most movement occurring at the southern end of the house exposed to the SW'ly wind. Wind speeds are shown below thermograph Chart No. 4.

14. DISCUSSION

For most of the time the fixed ventilators plus judicious opening of the end doors provided adequate ventilation of the house. The present work shows that night minimum temperatures in the house are very similar to those outside. Thus in extremely cold weather the main advantage of the house would be that the animals were kept dry and protected from the wind. Animals allowed to retain their fleece are unlikely to be cold stressed but shorn animals might suffer at extremely low temperature (-15°C has been recorded at Durham in the recent past) if for any reason the end doors of the house had to be kept open for any length of time, perhaps as emergency ventilators. In these conditions only light winds inside the house could cause shorn animals to suffer stress.

In snow fall the fine gauge plastic mesh of the end walls would no doubt become blocked and ineffective as a ventilator and in appreciable snow fall the air inlets along each side of the house would need to be kept clear to maintain a throughput of air.

In unusually warm conditions care will be necessary to ensure that the animals do not suffer stress due to overheating. This present work has shown how a temperature lift of 8°C over that outside occurred in the house in sunny but moderately windy

conditions. The highest outside temperature measured during this housing period was +12°C but inspection of the data for Durham during the period 1941-70 shows that the temperature in January to March was occasionally over 20°C. In such conditions, particularly in light winds, the house temperature could reach 30°C.

While the stock manager would always have the option of turning the animals out into the open for protection against excessive heat stress as much of a problem might be the stress induced by rapid changes of temperature. Although data for March in the north of England shows that outside temperature changes of 6°C in 3 hours occur only two or three times per month the rise of house temperature in the same interval could be as much as double this. The small modification already made to the end walls of this particular house has improved the ventilation but it might be prudent to have in such houses an emergency arrangement whereby the whole of the end walls could be removed quickly in rapidly rising temperatures in order to maintain safe levels of temperature. This might prove to be less costly than the labour involved in turning the stock out and later rehousing them.

It is clear that in warm weather conditions at least the stock manager will have to maintain a close watch on house conditions and be on hand to make adjustments to the ventilation arrangements. An accurate and properly housed thermometer would be invaluable to a stock manager.

15. NOTE ON THE INSULATING PROPERTIES OF BEDDING MATERIALS

Investigations made elsewhere on weather stress on sheep show that, out of doors, ewes spend up to 50% of the time sitting down during which time heat loss to the ground can amount to about half the heat provided by the animals natural food intake. Housed sheep are known to sit for up to 80% of the time and among the theories proposed to account for this increase in sitting time are that:-

(a) Housed animals do not have to spend time searching for food.

(b) Hand feeding induces competition and leads to a shorter time being spent feeding.

(c) The provision of a safe environment reduces the need to remain alert.

It is equally feasible, however, that in warm conditions these thickly fleeced, well insulated animals instinctively sit in order to rid themselves of excess heat. In this present work ewes were seen to even lie down in warm conditions so increasing the area of body in contact with the ground. Similar observations have been made in sheep houses at both Drayton EHF and Redesdale EHF (private communications).

The provision of clean dry straw bedding is necessary in sheep houses to protect the underlying natural ground from damage to keep the animals clean and to provide a cushion to safeguard the animal from damage where the floor is of concrete. Although the provision and replenishment of a deep dry straw bed is usually taken as an indication of good stockmanship, too thick a bed will deny to the ewe an important avenue of heat dissipation. Also, heat generated by fermentation in damp compacted bedding will further impede the transfer of excess heat away from the animals.

16. RECOMMENDATIONS ON CONSTRUCTION AND SITING

(a) A north-south orientation of a sheep house is preferred as such a house will take in less radiation from the sun during the usual housing period of December-March than will a house orientated E-W.

(b) Intake of the sun's radiation will be minimised if houses are placed on north facing slopes.

(c) Houses with an end to end height difference of 1-3 m in a typical 60 m long house will tend, in calm sunny conditions, to self ventilate by 'stack effect'. Further, waste and spilled liquids may be readily drained away.

(d) End walls, including doors should preferably be made entirely of mesh to allow air to pass readily. Such mesh should be white so as to reduce absorption of sun's radiation.

(e) Mesh covered end doors should extend to the full height of the end 'walls'.

(f) A main covering skin of white almost opaque plastic material will reflect away much of the sun's radiation. Transparent material should be avoided.

(g) Judiciously placed live or artificial shelter may lengthen the life of the covering material by reducing flexing due to the wind.

(h) The house should be within sight and easy reach of the stock manager's place of work to allow quick response to rapid changes of weather.

(i) Carefully sited thermometers, housed in simple anti-radiation screens should be used to monitor:-

i. the outside air temperature,

ii. the inside air temperature at the up-slope end of the house,

to alert the stock manager to open doors should large inside/outside temperature differences occur.

(j) Daily use should be made of the local weather forecasting service.

ACKNOWLEDGEMENTS

The ready co-operation and assistance of Mr D Turnbull of Gorfenletch Farm is gratefully acknowledged as is the provision of facilities and materials by Mr I Parry of the ADAS Office at Alnwick. The author is also grateful to Dr M N Hough of the ADAS Meteorological Office, Harrogate for assistance during installation and for advice during the preparation of this paper.

Any suggestions or comments on this paper should be made to the author.

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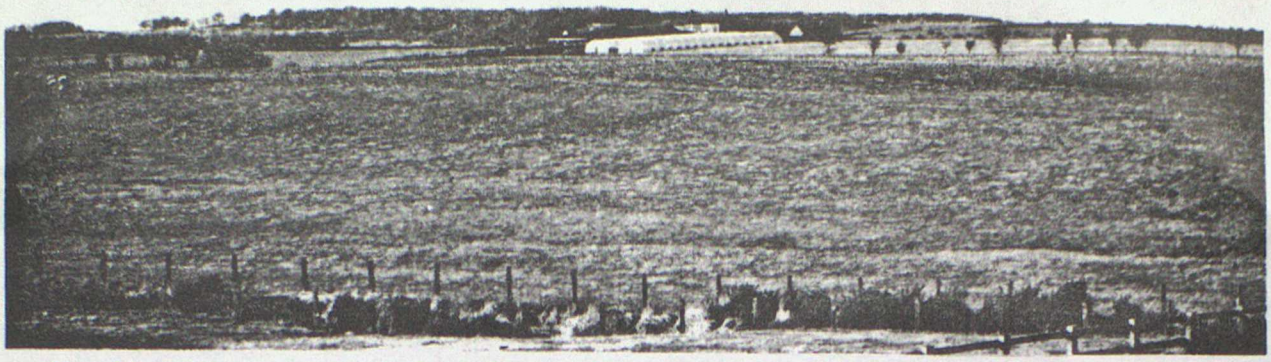
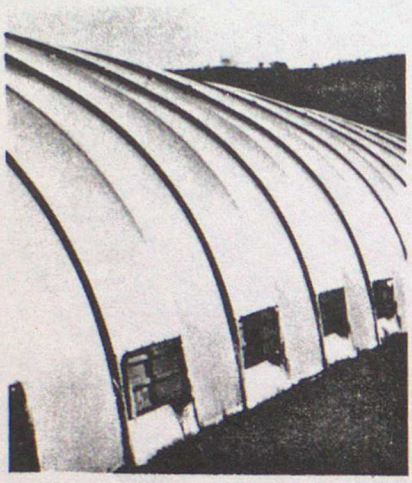
June 1981

Figs 1-9

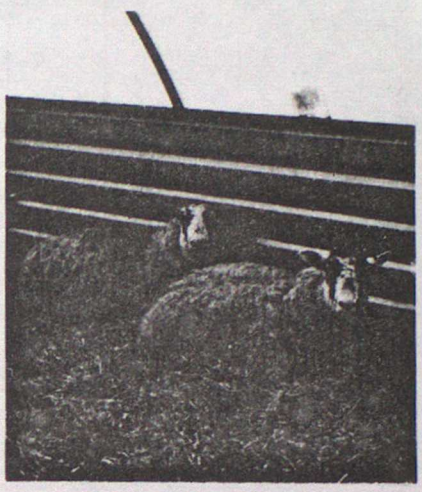


1. Sheep Houses at Gorfenletch Farm Note exposure and slope of ground



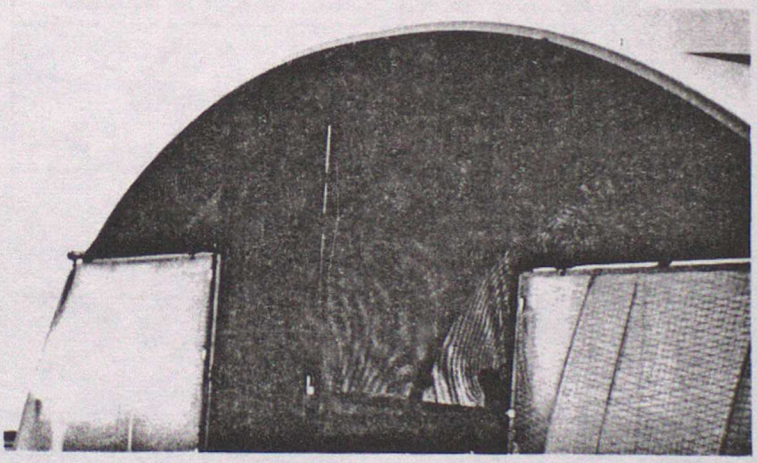
2. Side Vents

3. Roof Vents and Pens

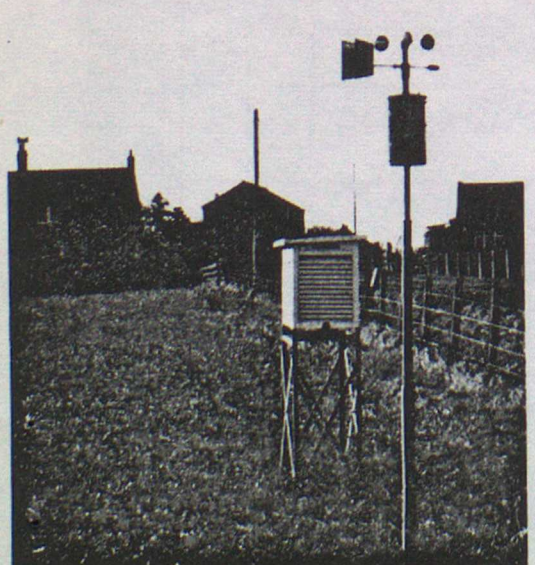


4. Metal Side Sheeting

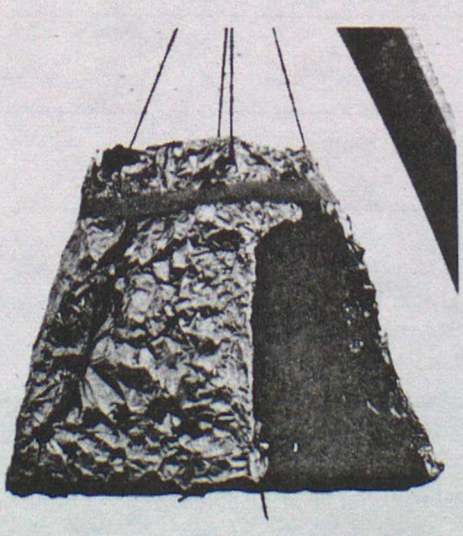
5. Original End Wall



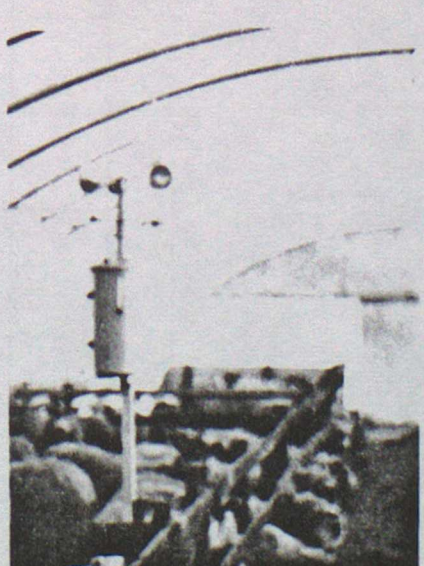
6. Modified End Wall



7. Field Met Site



8. Thermograph Housing



9. Woelfle in House

1st Period - 11-17 December 1980 - House Empty

TABLE 1

Hourly run of wind in Km

Hour	11th	12th	13th	14th	15th	16th	17th
00-01	14	16	9	21	34	11	20
2	8	10	12	27	29	12	20
3	8	9	9	26	26	11	16
4	10	9	7	16	26	13	19
5	15	11	11	15	24	12	18
05-06	13	17	12	12	23	6	16
7	12	17	16	6	15	6	17
8	13	20	16	11	17	6	18
9	15	16	15	17	13	7	19
10	19	22	22	23	8	9	15
11	21	24	22	22	10	7	21
11-12	23	30	28	26	10	10	21
13	25	33	25	30	20	10	22
14	19	34	26	28	19	11	19
15	11	28	24	32	19	11	17
16	13	30	20	38	16	14	14
17	12	29	17	48	19	18	11
17-18	11	22	17	49	23	16	12
19	14	23	21	45	22	19	10
20	10	27	22	37	26	21	14
21	10	24	19	37	22	22	17
22	10	19	22	39	20	18	16
23	11	19	20	35	12	18	18
23-24	8	14	20	41	11	25	17
Total	324	503	432	681	464	313	407
Mean	13.5	20.9	18.0	28.4	19.3	13.0	17.0

Mean speed for whole period = 18.6 Km/hr

TABLE 2

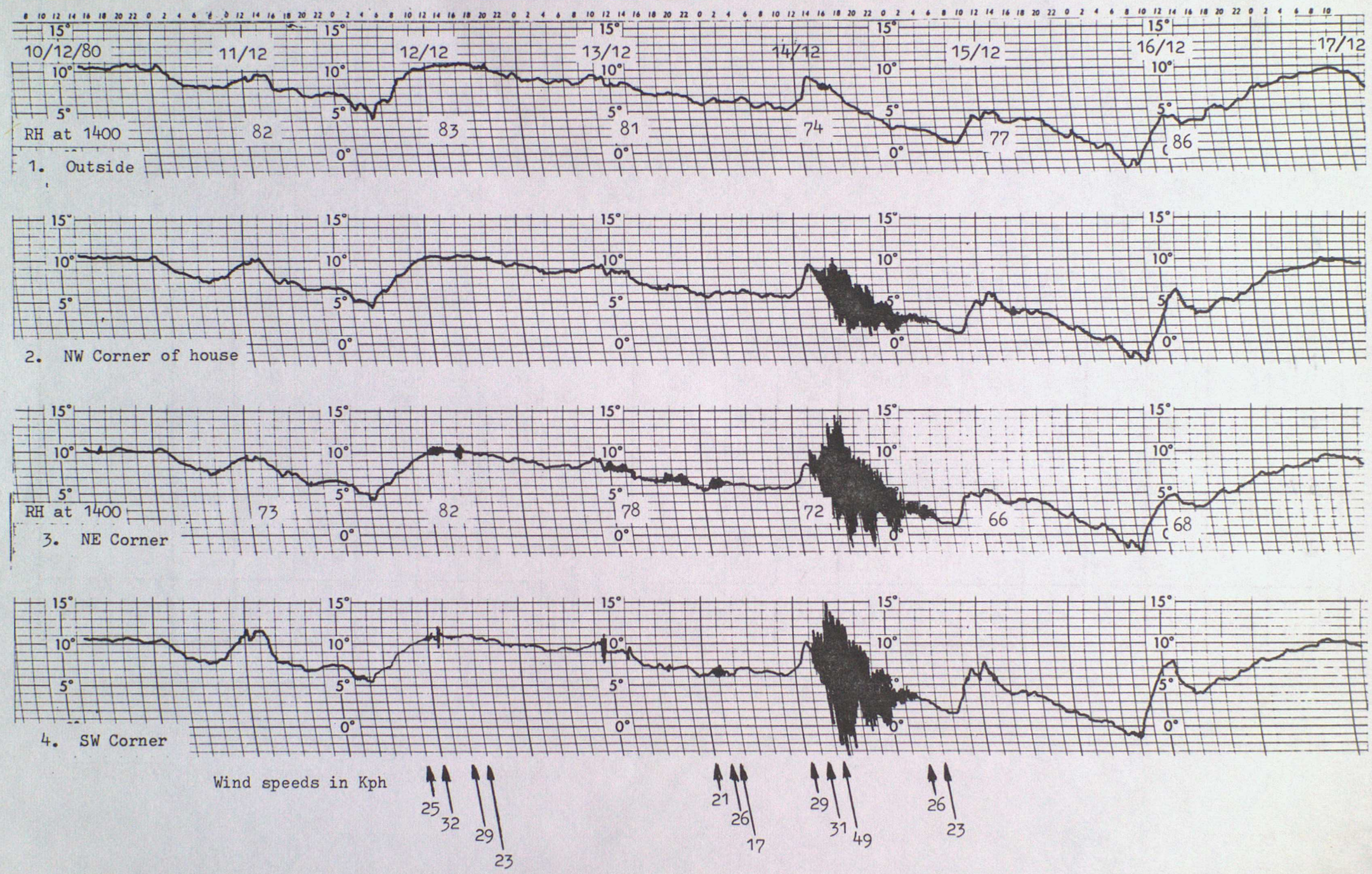
Max and Min Temperatures

Inst. Site		11th	12th	13th	14th	15th	16th	17th	Mean Max	Mean Min
Outside	Max	10.8	10.9	9.3	9.2	4.9	7.6	9.7	8.9	
	Min	6.9	4.3	5.8	2.8	1.0	-2.0	7.5		3.7
NW	Max	10.7	10.6	9.6	9.4	6.1	6.9	10.1	9.1	
	Min	6.6	4.3	5.5	6.7	1.2	-2.2	6.9		4.1
NE	Max	10.4	11.0	9.2	8.5	5.3	6.7	9.5	8.7	
	Min	6.0	4.2	5.3	3.9	1.2	-2.1	6.8		3.6
SW	Max	11.8	11.2	10.0	10.1	7.8	8.0	10.3	9.9	
	Min	6.8	5.5	6.0	2.8	1.6	-1.4	7.4		4.1

Mean Max Inside	9.2	
Mean Min Inside		3.9

THERMOGRAPH CHARTS 1-4

1st Period. 11th-17 Dec (House empty)



2nd Period - 7-13 January 1981 - 230 Ewes Housed

TABLE 3

Hourly run of wind in Km

Hour	7th	8th	9th	10th	11th	12th	13th
00-01	17	25	27	30	18	30	31
2	13	21	22	32	12	30	32
3	6	15	21	31	13	20	31
4	6	14	16	34	14	15	26
5	6	17	15	27	15	20	19
05-06	8	17	14	26	14	24	17
7	8	21	15	34	13	20	17
8	8	13	13	31	13	21	16
9	8	13	17	31	15	19	17
10	7	12	12	26	17	19	20
11	8	16	10	28	10	17	16
11-12	9	21	14	26	12	17	15
13	11	18	17	24	13	27	16
14	7	19	17	30	15	30	17
15	8	16	14	34	13	29	21
16	14	23	13	26	14	19	22
17	14	21	17	26	13	30	22
17-18	12	19	14	25	19	26	21
19	16	15	15	24	19	29	24
20	14	23	10	20	31	42	26
21	13	24	16	16	22	38	19
22	14	25	20	16	24	34	17
23	17	28	28	17	20	31	16
23-24	26	28	26	16	23	31	19
Total	270	464	403	630	392	618	497
Mean	11.3	19.3	16.8	26.3	16.3	25.7	20.7

Mean speed for whole period = 19.5 Km/hr

TABLE 4

Max and Min Temperatures

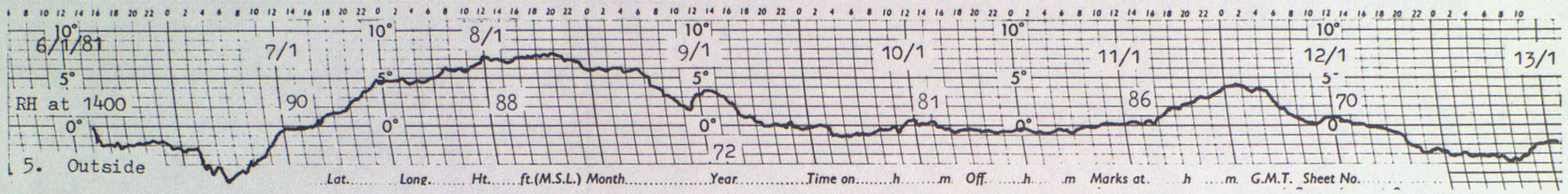
Inst. Site		7th	8th	9th	10th	11th	12th	13th	Mean Max	Mean Min
Outside	Max	4.7	7.6	6.1	0.6	4.0	4.2	-1.8	3.6	
	Min	-6.0	-4.4	-0.3	-1.2	-0.9	-2.9	-4.0		-2.8
NW	Max	4.5	8.3	6.9	0.9	4.7	4.7	0.4	4.3	
	Min	-5.0	4.5	-1.0	-1.7	-0.4	-3.6	-3.3		-0.5
NE	Max	6.0	9.1	7.6	2.1	4.9	5.2	1.1	5.1	
	Min	-3.4	5.5	0.0	-0.7	0.3	-1.2	-2.2		-0.2
SW	Max	4.3	7.8	8.7	2.7	3.6	4.0	-1.0	4.3	
	Min	-5.4	4.3	0.3	-0.6	0.2	-2.8	-3.4		-0.1

Mean Max Inside	4.6	
Mean Min Inside		-0.9

THERMOGRAPH CHARTS 5-8

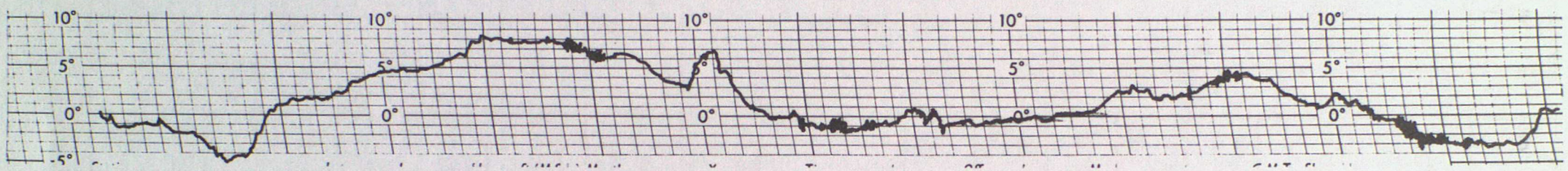
2nd Period. 7th-13th Jan '81

(220 Ewes housed)

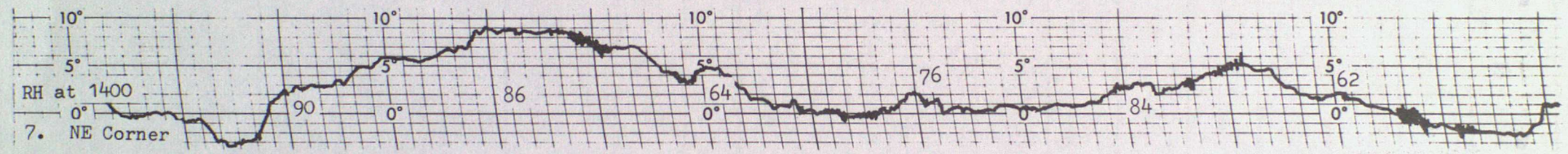


5. Outside

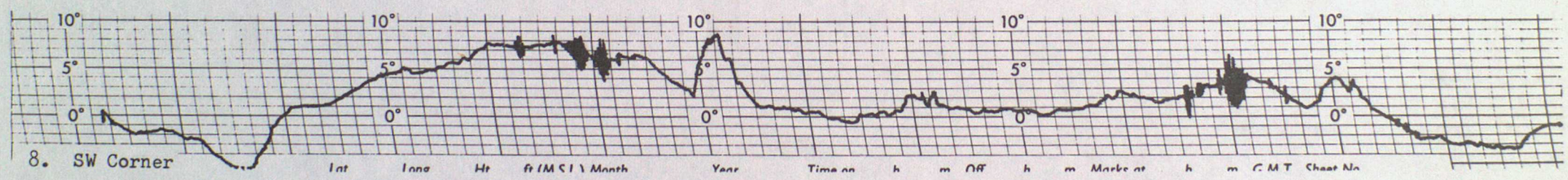
Lat..... Long..... Ht.....ft.(M.S.L.) Month.....Year.....Time on.....h.....m Off.....h.....m Marks at.....h.....m G.M.T. Sheet No.



6. NW Corner of house



7. NE Corner



8. SW Corner

Lat Long Ht ft.(M.S.L.) Month Year Time on h m Off h m Marks at h m G.M.T. Sheet No.

2nd Period - 15-21 January 1981 - 230 Ewes Housed

TABLE 5

Hourly run of Wind in Km + Direction and r.o.w. in house

Hour	15th	16th	17th	18th	19th	20th	21st
00-01	21	10	16	6	20	14	8
2	20	14	17	4	21	11	11
3	19	8	14	5	21 N1	15 N1	15
4	21	7	11	4	17	13	13
5	22	8	5	4	16	11	10
05-06	20	5	8	4	14	11	12
7	21	4	10 S1	5	19 N1	12	11
8	20	6	7	5	23 N1	12	15
9	19	3	3	5	22 N1	10	14
10	19	3	4	9	22 N1	8	15
11	27	6	9	10 S1	19 N1	8	14
11-12	21	13 S1	9	14 S2	26 N1	7	13
13	15	13 S1	10	13 S1	20 N1	7	18
14	17	16 S1	16 N1	15 S2	19 N1	5	15
15	13	21 S1	16 N1	18 S2	11 N1	4	13 1
16	8	22 S1	18 N1	20 S2	10	5	24
17	8	17 S1	18 N1	19 S2	8	7	30 1
17-18	9	9	16 N1	19 S2	10	6	21 1
19	7	6	11	19 S2	9	5	22
20	6	5	9	7	8	4	19
21	6	5	9	5	7	6	11
22	6	11	8	16	9	10	11
23	7	14	6	16	11	9	7
23-24	12	19	9	16	14	9 N1	13
Total	364	245	259	253	376	209	355
Mean	15.2	10.2	10.8	10.7	15.7	8.7	14.8

Mean speed for whole period = 12.3 Km/hr

TABLE 6

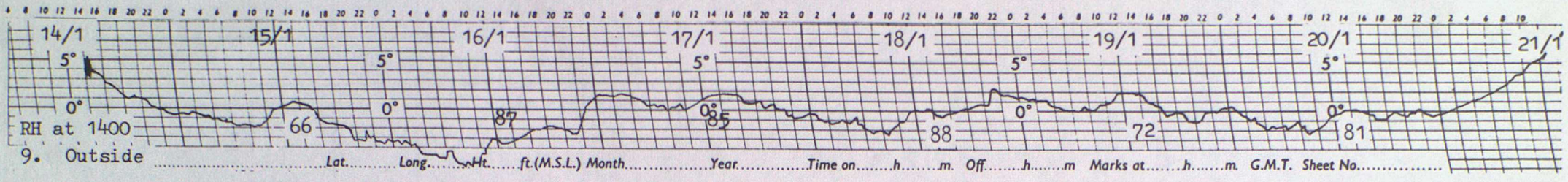
Max and Min Temperatures

Inst. Site		15th	16th	17th	18th	19th	20th	21st	Mean Max	Mean Min
Outside	Max	0.7	1.3	1.7	2.3	2.0	0.4	8.0	2.3	
	Min	-3.5	-6.0	-0.8	-2.3	-1.2	-2.2	-0.3		-2.3
NW	Max	4.0	1.0	3.0	2.1	4.4	2.3	8.7	3.6	
	Min	-4.3	-6.0	-0.3	-2.2	-0.9	-2.0	1.0		-2.1
NE	Max	2.1	2.0	4.3	3.1	3.3	3.6	8.6	3.9	
	Min	-2.9	-4.3	0.3	-1.3	0.0	-0.7	2.5		-0.9
SW	Max	5.9	1.4	3.8	2.4	6.9	2.0	8.6	4.4	
	Min	-3.8	-5.6	0.3	-2.2	-0.6	-2.0	0.2		-1.9

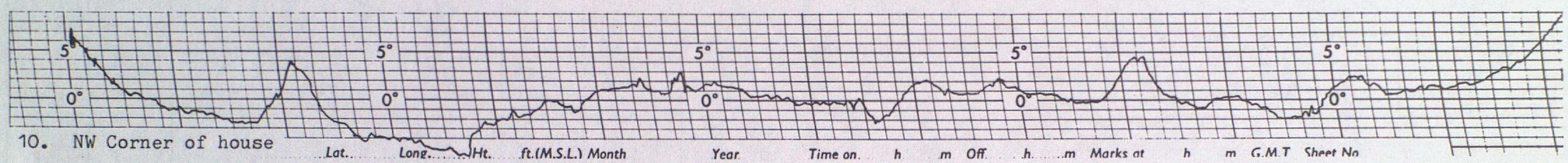
Mean Max Inside	4.0	
Mean Min Inside		-1.6

THERMOGRAPH CHARTS 9-12

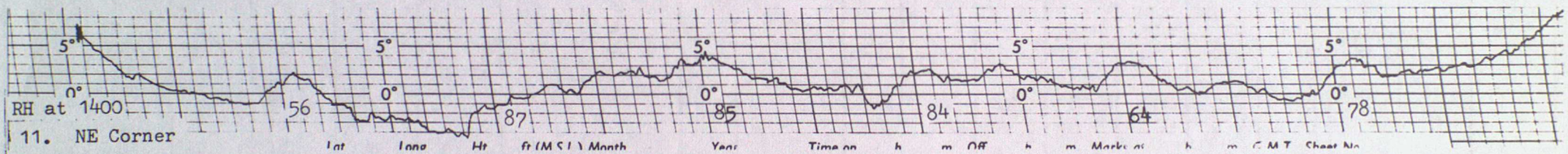
2nd Period. 15th-21st Jan '81 (220 Ewes housed)



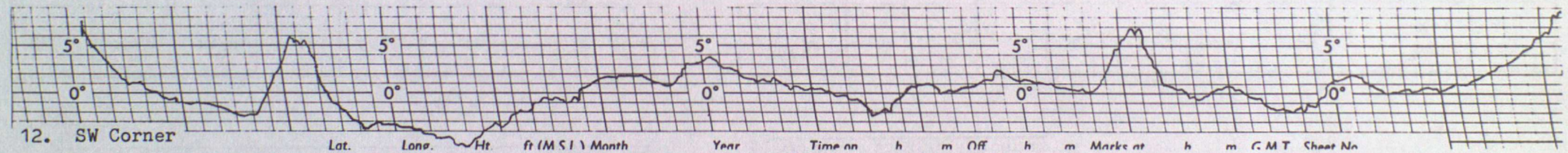
9. Outside ..... Lat..... Long..... Ht..... ft.(M.S.L.) Month..... Year..... Time on.....h.....m. Off.....h.....m Marks at.....h.....m. G.M.T. Sheet No.....



10. NW Corner of house ..... Lat..... Long..... Ht..... ft.(M.S.L.) Month..... Year..... Time on.....h.....m. Off.....h.....m Marks at.....h.....m. G.M.T. Sheet No.....



11. NE Corner ..... Lat..... Long..... Ht..... ft.(M.S.L.) Month..... Year..... Time on.....h.....m. Off.....h.....m Marks at.....h.....m. G.M.T. Sheet No.....



12. SW Corner ..... Lat..... Long..... Ht..... ft.(M.S.L.) Month..... Year..... Time on.....h.....m. Off.....h.....m Marks at.....h.....m. G.M.T. Sheet No.....

2nd Period (Week 3) - 22-28 January 1981 - 230 Ewes Housed

TABLE 7

Hourly run of Wind in Km + Direction and r.o.w. in house

Hour	22nd	23rd	24th	25th	26th	27th	28th
00-01	8	8	25 S1	19	3	15	16
2	15	9	24 S1	19	2	17	12
3	21	10	15	18	4	11	11
4	18	12	19	14	2	10	12
5	18	8	16	10	10	14	14
05-06	14	10	12	9	10 1	15	16
7	5	12	11	6	11 1	9	16
8	6	15	9	9	14 1	12	19
9	2	16 1	7	11	11 1	14	12
10	5	15	9	14	5	13	13
11	6	21	9	16	7	13	13
11-12	7 1	23	19	18 N1	9	11	13
13	11	13	22	18 N2	13	17	16
14	10	15	15	13	15	16	15
15	10	13	13	14	14	13	18
16	12	10	14	11	14	13	16
17	15	10	12	10	14	10	17
17-18	17	9	15	12	11	11	12
19	10	9	13	10	12	14	15
20	14	13	13	10	17	13	18
21	11	19 2	15	8	15	13	12
22	9	20 2	20	7	9	13	16
23	11	15 1	17	4	11	15	21
23-24	10	19 1	21	3	14	16	23
Total	265	324	365	283	256	318	366
Mean	11.0	13.5	15.2	11.8	10.7	13.3	15.3

Mean speed for whole period = 13.0 Km/hr

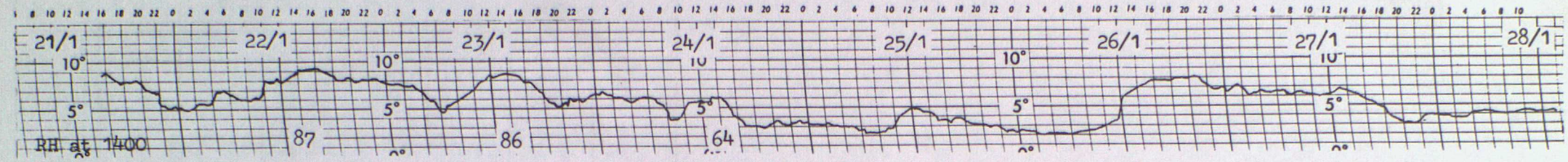
TABLE 8

Max and Min Temperatures

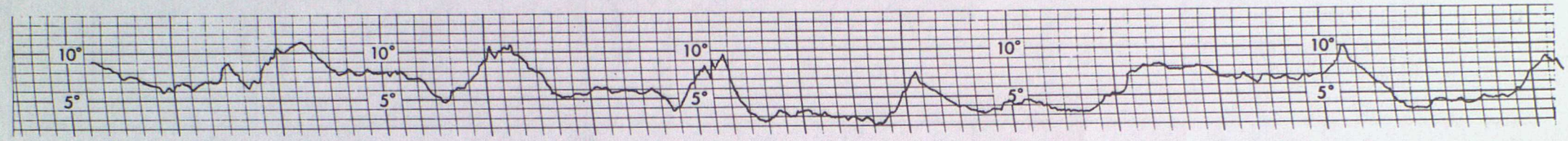
Inst. Site		22nd	23rd	24th	25th	26th	27th	28th	Mean Max	Mean Min
Outside	Max	9.2	8.7	6.8	4.9	8.0	7.2	4.3	7.0	
	Min	4.9	4.7	2.9	3.3	2.0	3.0	3.7		3.5
NW	Max	11.1	10.7	9.6	7.5	8.3	10.0	8.7	9.4	
	Min	5.9	4.8	2.6	2.0	3.3	3.3	3.5		3.6
NE	Max	11.8	10.8	8.7	6.8	8.8	9.2	9.3	9.3	
	Min	6.9	5.3	3.0	2.9	3.8	4.0	4.5		4.3
SW	Max	10.1	11.1	10.1	9.0	8.7	10.0	8.0	9.6	
	Min	5.5	5.0	3.2	2.6	2.6	3.2	4.2		3.7

Mean Max Inside	9.4	
Mean Min Inside		3.9

THERMOGRAPH CHARTS 13-16 — 2nd Period. 22nd-28th Jan '81 — (220 Ewes housed)



13. Outside



14. NW Corner of house

15. NE Corner

16. SW Corner

3rd Period - (Week 1) - 3-9 March 1981 - 230 Ewes Housed

TABLE 9

Hourly run of Wind in Km + Direction and r.o.w. in house

Hour	3rd	4th	5th	6th	7th	8th	9th
00-01		7	8	19 S1	12 S1	23 S1	9
2		6	5	19 S2	16 S1	21	15
3		7	8	18 S2	12 S1	19	25
4		4	11	17 S2	11 S1	16 S1	26
5		5	7	13 S1	17 S2	22 S2	22
05-06		7	6	19 S1	16 S2	18	20
7		5	4	17 S1	16 S2	19	16
8		6	4	14 S1	24 S1	16 S1	9
9		8	5	16 S2	30 S4	22 S3	17
10		8	5	11 S1	24 S4	19 S3	20
11		12	3	12 S1	27 S4	18 S3	14
11-12		13	2	16 S1	27 S1	19 S2	14
13		12	4	16	28 S2	19	9
14		10	6	20	32 S3	16	4
15		11	8	21	34 S3	20	7
16		9	10 S1	19	33 S3	22 S1	9
17	16	10	12 S1	15	29 S2	27 S1	8
17-18	9	7	10 S1	7	28 S3	19	9
19	6	6	10 S1	6	24 S2	12	9
20	6	10	11 S1	3	20 S1	8	10
21	5	7	15 S1	3	18	5	11
22	6	7	14 S1	7	21 S1	5	12
23	7	11	17 S1	4	19 S1	11	12
23-24	6	7	19 S1	5	20 S1	10	15
Total	61	195	204	317	538	406	322
Mean	7.6	8.1	8.5	13.2	22.4	16.9	13.4

Mean speed over whole period = 12.9 Km/hr

TABLE 10

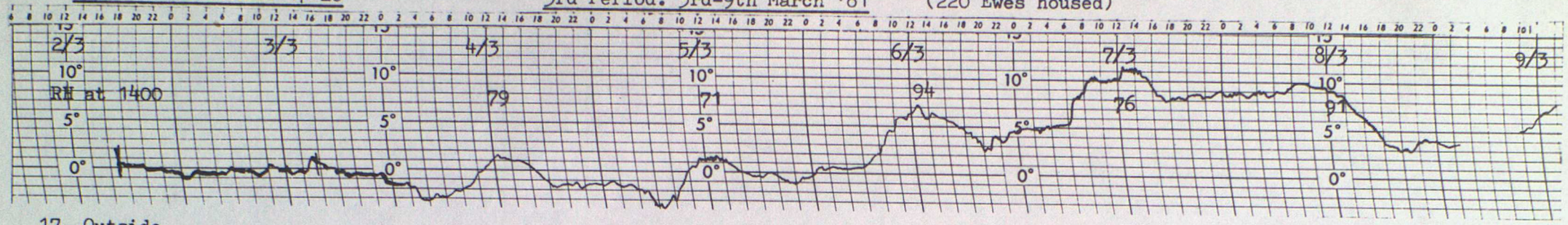
Max and Min Temperature

Inst. Site		3rd	4th	5th	6th	7th	8th	9th	Mean Max	Mean Min
Outside	Max	1.2	1.6	1.6	7.2	11.3	10.0	8.0	5.8	
	Min	-1.6	-3.2	-4.0	-0.4	4.5	2.9	3.5		0.2
NW	Max	2.2	7.0	9.1	11.8	16.5	13.8	12.6	10.4	
	Min	-0.6	-2.0	-2.8	1.0	6.0	4.3	4.2		1.4
NE	Max	3.9	6.3	8.3	10.8	15.6	13.4	11.9	10.0	
	Min	1.0	0.0	-0.3	2.5	7.0	5.4	5.0		2.9
SW	Max	3.4	6.8	7.8	11.5	15.9	12.7	14.8	10.4	
	Min	0.4	-2.0	-2.0	1.0	6.2	4.4	4.7		1.8

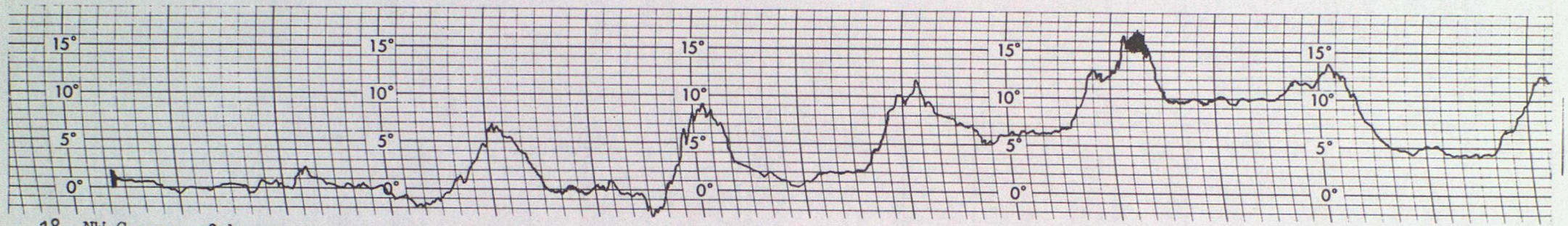
Mean Max Inside	10.3	
Mean Min Inside		2.0

THERMOGRAPH CHARTS 17-20

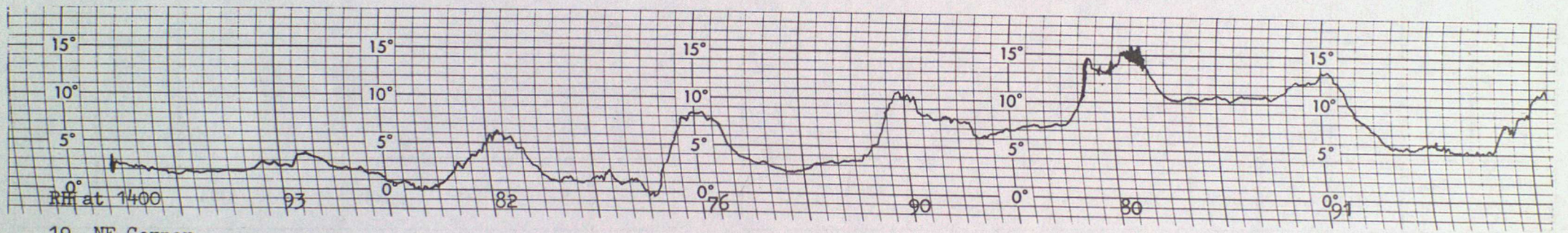
3rd Period. 3rd-9th March '81 (220 Ewes housed)



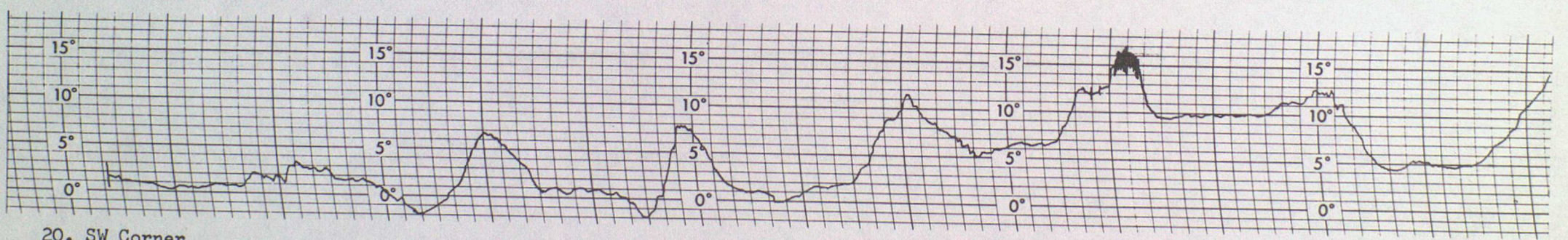
17. Outside



18. NW Corner of house



19. NE Corner



20. SW Corner

3rd Period - (Week 2) - 10-16 March 1981 - 230 Ewes Housed

TABLE 11

Hourly run of Wind in Km + Direction and r.o.w. in house

Hour	10th	11th	12th	13th	14th	15th	16th
00-01	16	5	8	3	9	13	5
2	16	8	9	3	8	11	9
3	16	7	10	3	9	9	8
4	18	5	9	2	14	11	6
5	20	9	8	2	13	11	7
05-06	23	6	8	1	17	8	5
7	22	6	8	1	14	10	9
8	27	8	8	5	14	10	9
9	25	9	8	6	12	10	12
10	20 S2	10	7	7	14	14	17 N1
11	17 S2	13	10	8	15 N1	13 N2	17 N1
11-12	14 S1	19	13	11	14	10 N1	21
13	13 S2	20	13	1	16 N1	21 N1	20
14	9 S1	21	13	9	16 N2	12 N1	20
15	7	22	9	9	14 N1	12 N1	20 N3
16	14	20	9	9	14	9	20 N2
17	19 S1	17	9	9	17	6	21 N2
17-18	15	15	9	10	14	5	21 N1
19	8	13	7	10	10	11	17
20	10	15	5	7	10	14	19
21	7	10	5	11	10	7	18
22	6	11	5	11	11	5	22
23	7	10	4	9	11	5	26
23-24	4	8	4	7	12	4	25
Total	353	287	198	164	308	241	374
Mean	14.7	11.9	8.3	6.8	12.8	10.0	15.6

Mean speed over whole period = 11.4 Km/hr

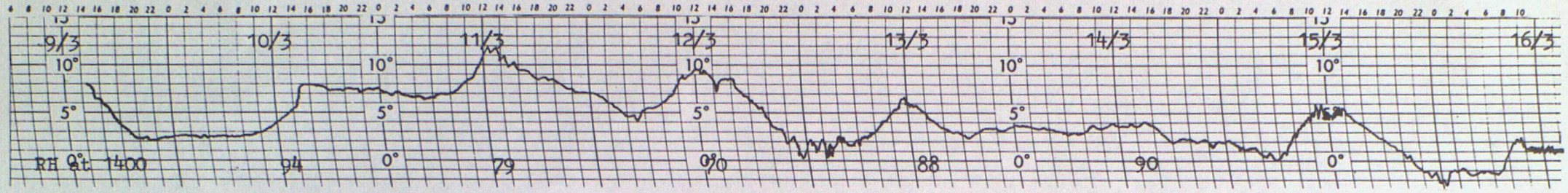
TABLE 12

Max and Min Temperatures

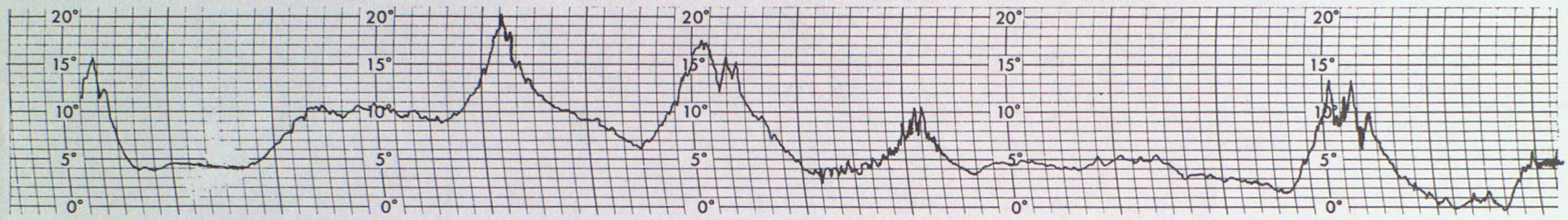
Inst. Site		10th	11th	12th	13th	14th	15th	16th	Mean Max	Mean Min
Outside	Max	8.0	12.0	9.6	6.7	4.1	6.0	2.5	7.0	
	Min	2.4	6.4	0.2	0.2	1.5	-2.2	-2.5		0.9
NW	Max	10.9	20.1	17.5	10.5	5.5	13.5	5.8	12.0	
	Min	4.0	8.8	4.4	3.6	2.8	0.4	-0.4		3.4
NE	Max	11.5	16.2	16.0	11.7	7.2	9.2	5.6	11.1	
	Min	5.4	9.3	4.6	4.2	4.0	2.1	1.6		4.5
SW	Max	9.5	19.0	16.6	14.0	7.8	14.2	7.6	12.7	
	Min	3.1	8.2	3.0	3.9	4.3	-0.2	-0.1		3.2

Mean Max Inside	11.9	
Mean Min Inside		3.7

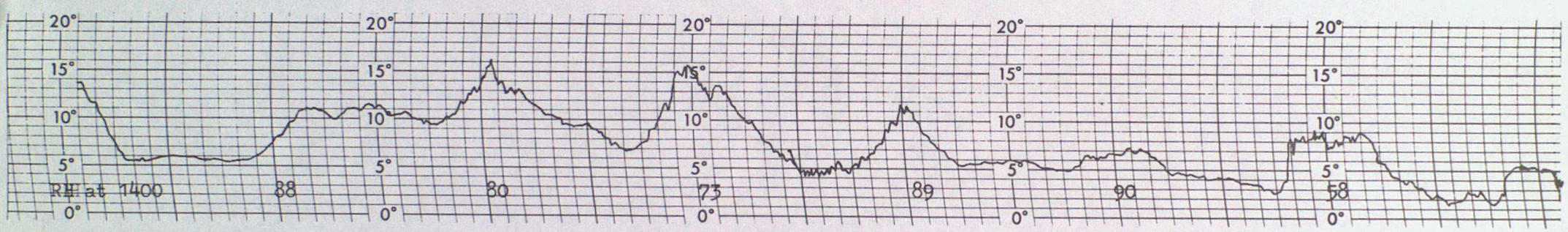
THERMOGRAPH CHARTS 21-24 — 3rd Period. 10th-16th March '81 (220 Ewes housed)



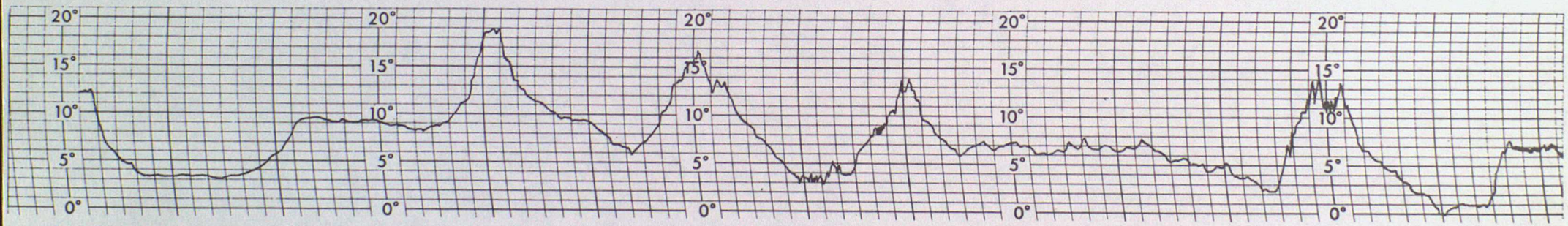
21. Outside



22. NW Corner of house



23. NE Corner



24. SW Corner